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Cambrian sediments and Proterozoic granites in the Dividalen-Torneträsk area, northern Scandinavia: Palaeomagnetism and U–Pb geochronology

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Abstract: New palaeomagnetic data from the autochthonous Early Cambrian Dividal Group (northern Scandinavia) confirm earlier findings, and a refined palaeomagnetic pole of 58.4°N and 122.5°E, places Baltica at intermediate southerly latitudes at ~535 Ma. Palaeomagnetic data from the immediately underlying granitic basement (pole: 9.8°N, 226.7°E) differ markedly from the Dividal sediments. The result of this fieldtest increases the palaeomagnetic reliability of the Dividal Group results. We dated the granitic basement in the eastern part of the Torneträsk area (corresponding to our palaeomagnetic site) to 1786±4 Ma (U–Pb zircon and titanite), whilst deformed allochthonous granites west of lake Torneträsk are slightly older (1800±4 Ma; U–Pb zircon). These ages are compatible with autochthonous basement ages to the east of the study area, but also with ages from basement windows to the west. Preliminary palaeomagnetic data from the 1786±4 Ma granitic basement are clearly pre-Phanerozoic in origin, and comparable and concordant zircon and titanite ages may hint that the magnetisation could be primary. However, the palaeomagnetic pole does not match contemporaneous poles from Baltica, which suggest a tectonic explanation (no palaeohorizontal control), a problem of secular variation (only one site) or a younger but pre-Phanerozoic remagnetisation event, which did not affect the U–Pb system in zircon and titanite.

Keywords: Cambrian sediments, palaeomagnetism, Proterozoic granites, geochronology, Baltica apparent polar wander path, palaeogeography

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Introduction and geological background

When evaluating the palaeogeographic positions of continents through time, the Early Cambrian is an important period because of the controversy surrounding the hypothesis of 90° Early Cambrian true polar wander (TPW) linked to the Cambrian faunal radiation (Kirschvink et al. 1997). A positive test for this hypothesis would require that every continent at this time should reveal a similar amount (c. 90°) of apparent polar wander (APW) because TPW supposedly occurred within a relatively short period (535–520 Ma). Palaeomagnetic poles and the APW path for Baltica have so far not shown such dramatic changes, but the Early Cambrian period is admittedly a palaeomagnetically difficult one. In Scandinavia, there are no known Early Cambrian products of igneous activity, and the Early Cambrian sedimentary record in southern Scandinavia is dominated by coarse-grained, quartz dominated sandstones (e.g. Bornholm-Denmark: Prasad & Sharma 1978; Lewandowski & Abrahamsen 1999, and Skåne-Sweden; Torsvik & Rehnström 2001) that have proven to be notoriously complicated for palaeomagnetic studies. In northern Scandinavia the Early Cambrian is represented by the Dividal Group (Jensen & Grant 1998), which is a better candidate for palaeomagnetic studies, since it consists partly of reddish mudstones and siltstones. However, in many places the Dividal Group is now part of the Mid-Palaeozoic Caledonian allochthon and has thus not only been displaced from its original position, but has also been subjected to deformation and metamorphism; hence undisturbed sampling locations are difficult to find. The autochthonous Dividal Group is primarily found in close proximity to the Caledonian front (Fig. 1A). We reconnaissanced four potential localities of the Dividal Group in Norway, Sweden and Finland, but due to problems with accessibility and lack of good rock exposure, only two new areas were sampled. Vogt (1967) and Kulling (1964) have explored the regional distribution of the Dividal Group in Norway and Sweden respectively, whilst Thelander (1982) undertook a detailed sedimentological analysis of the different members of the Dividal Group.

Bylund (1994) and Torsvik & Rehnström (2001) have previously reported palaeomagnetic data from the Dividal Group, from Dividalen (Norway) and the Luovarri sections (Sweden), respectively. These data are directionally consistent, but it is important to increase the reliability of the Early Cambrian palaeopole with additional studies. In this study we present additional palaeomagnetic data from the Red and Green Siltstone member from the Dividalen type locality in Norway and the Lower Siltstone member from the Vakkejokk locality in the Swedish Torneträsk area (Fig. 1A). The latter is in close proximity to the Luovarri locality of Torsvik & Rehnström (2001). A regional stability test, in this study, includes the first palaeomagnetic and U–Pb zircon geochronological results from the Precambrian granitic basement immediately underlying the Dividal Group. The regional stability test is important to confirm the primary nature of the remanent magnetisation in the overlying Cambrian sediments.

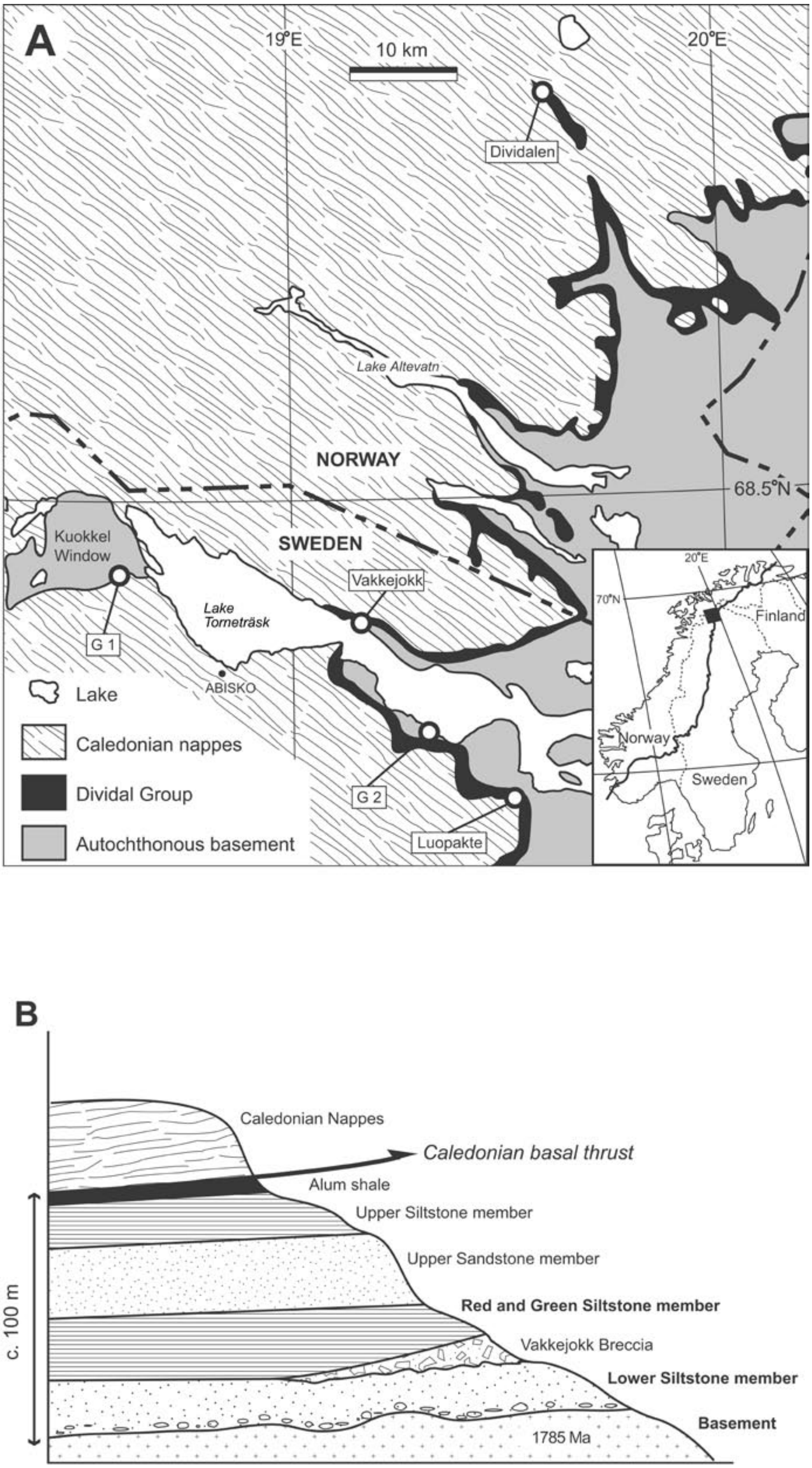

Fig. 1. **A.** Simplified geological map showing the sampling localities, modified from Silvennoinen et al. (1987). **B.** Schematic section of the Dividal Group (from Sweden). The indicated thicknesses refer to mean stratigraphic thickness within the studied areas. Stratigraphic members in bold letters refer to the sampled ones (after Thelander 1982).

Sampling localities and local geology

The Dividal Group in northern Sweden consists of a variety of clastic sediments deposited on a Precambrian peneplain (Fig. 1B). The entire Group ranges in grain size from very coarse-grained conglomerates above the basal unconformity to shaly members. It also contain some calcareous lithologies. The horizons of specific interest are the so-called Red and Green Siltstone member and the Lower Siltstone member (Thelander 1982; Jensen & Grant 1998). The Red and Green Siltstone member is a trace horizon in northern Scandinavia and consist of siltstones and fine-grained sandstones, sometimes with a conspicuous red coloration. Thelander (1982) interpreted this member to have formed in response to an extensive marine transgression.

The Dividal Group was interpreted as Vendian (e.g. Føyn 1985) until Jensen and Grant (1998) discovered Early Cambrian trace fossils in the Lower Siltstone member, underlying the Red and Green Siltstone member. Both the Lower Siltstone member and the Red and Green Siltstone member have been correlated with the Siberian Nemakitian-Daldynian (Torsvik & Rehnström 2001), which has an assigned mean age of 535 Ma.

Dividalen (Norway)

The sampling was done at Nedre Divifossen (68.83°N, 19.61°E), in a river section that exposes the Red and Green Siltstone member (Level D of Vogt 1967). The sampled red siltstone has a heterogeneous mottled appearance in red and green colours. It is generally massive, but is transected by small fractures filled with chlorite and calcite. The red siltstone is both under and overlain by a greenish shale with a much more pronounced schistosity within the same member. Drill-cores were sampled within 60 cm of stratigraphic thickness.

Vakkejokk (Torneträsk, Sweden)

The lower part of the Vakkejokk rivulet (68.39ºN, 19.15ºE) transects subhori-zontal layers of Lower Cambrian strata, including both the Lower Siltstone and the Red and Green Siltstone members. Kulling (1964), and later Thelander (1982), have described the section in great detail (see also Fig 1B). The lowermost beds sampled are within the Lower Siltstone member, where Jensen and Grant (1998) described Cambrian trace fossils. The siltstone has a dark grey colour and consists of interbedded thin layers of differing grain size. Sedimentary features such as current ripples and larger scale cross-bedding are common. Thelander (1982) interpreted the Lower Siltstone member as tidal lagoon deposits. All drill cores were sampled within 60 cm of stratigraphic thickness and generally lacked fractures, veins or deformational fabric.

The Vakkejokk section, contrary to the Luovarri site (Torsvik & Rehnström 2001), lacks the red variety of the Red and Green Siltstone member and consists of green shales with a pronounced planar cleavage; these rocks were found unsuitable for palaeomagnetic analysis and therefore not sampled.

Kuokkel Window (Torneträsk, Sweden)

The lithologically heterogeneous crystalline basement underlying the Caledonides and the Early Cambrian in the Torneträsk area is exposed along the road between Kiruna and Narvik. The basement outcrops in the Kuokkel Window (Fig. 1A) are regarded as allocthonous (cf. Bax 1989; Kathol 1989; Romer & Bax 1992). The sample taken for U–Pb geochro-nology is a medium-grained white granite intruded by mafic dykes. Quartz and two feldspars, together with minor amounts of amphibole and biotite, compose the granite. As an accessory mineral, zircon is very abundant, but titanite is absent. This site is part of the Caledonian nappes and the granite itself has a distinct, although not pronounced, fabric. A Caledonian disturbance in this area is also apparent from isotopic analysis of zircon (see below), and this locality was supposed to be unsuitable for palaeomagnetic sampling.

Lake Torneträsk, Sweden

The autochthonous granite located at the eastern part of lake Torneträsk (68.30ºN, 19.25ºE; Fig. 1A), is a medium to coarse-grained red granite, with primary mineral assemblage of K-feldspar, quartz and biotite, with subordinate plagioclase, hornblende, pyrite, chlorite, zircon and titanite. The granite is horizontally jointed, but does not show any other signs of deformation and therefore this locality were considered more favourable for palaeomagnetic sampling than the basement in the Kuokkel Window.

Analytical methods

Geochronology

Zircon was analysed using isotope dilution thermal ionisation mass spectrometry (ID-TIMS) following the procedure of Krogh (1973). The two samples for geochronological analysis were crushed, ground and separated on a water-shaking table and with magnetoseparator. Different mineral fractions were selected based on differencies in colour, aspect ratio and size. The fractions used for analysis were then handpicked before air-abrasion (Krogh 1982) and the grains were washed in dilute nitric acid and rinsed with water and acetone. The samples were spiked with a mixed ^{205}Pb/^{235}U spike and then dissolved, zircon samples in Teflon bombs and titanite samples in Savillex vials (Krogh 1973). Zircon samples >3 μg were subjected to chemical separation following the procedures outlined by Corfu and Noble (1992) and Corfu and Stone (1998) and titanite samples following Corfu & Evins (2002), although modified using a single stage hydrochloric–hydrobromic acid procedure (Paper I in Rehnström 2003). The isotopic ratios of U and Pb were measured on a Finnigan MAT 262 mass spectrometer in static mode using Faraday cups, or, for small samples, in dynamic mode with an ion-counting secondary electron multiplier (SEM). The Pb and U data were corrected for 0.1%/AMU fractionation with an additional bias correction for the SEM measurements. The correction for initial lead composition was made using compositions modelled by Stacey and Kramers (1975). The resulting isotopic ratios were analysed with the ISOPLOT program (Ludwig 1999). The analytical work was performed at the Isotope laboratory at the Geological Museum, University of Oslo.

Palaeomagnetism

All palaeomagnetic samples were drilled in the field. The natural remanent magnetisation (NRM) was measured with a JR5A and a 2G SQUID magnetometer. Stability of a NRM was tested by thermal (MMTD-60 furnace) and alternating field (AF) demagnetisation (two-axis tumbler and 2G static demagnetisation). Curie temperatures were measured on a horizontal translation Curie balance, built at the Norwegian Geological Survey (NGU), whilst bulk susceptibility was measured on a KLY-2 kappabridge. Laboratory experiments were carried out at NGU and Lund University.

Results and interpretation

U–Pb geochronology

The results of the isotopic analysis of the two granite samples are listed in Table 1 and 2 and illustrated in Fig. 2. Sample G1 comes from the basement in the Kuokkel Window located just west of lake Torneträsk (Fig. 1A), whilst sample G2 is the same granite that as has been palaeomagnetically studied (see below).

The G1 sample has pink prismatic zircon grains of excellent quality and grains chosen for analyses lacked inclusions and fractures. Grains with prismatic habitus were preferred vs. multifaceted grains, in order to avoid inherited cores. Only abraded fractions were run (Table 1). The analysed G1 multi-grain zircon fractions are 0–9 % discordant. The uppermost analysis yields a concordia age of 1800±4 Ma (Fig. 2A), interpreted as the age of crystallisation. This age is also used to anchor a discordia line with all the data. The discordia is not well defined, but point to a lower intercept at 420±110 Ma, indicating a Mid-Palaeozoic partial lead-loss, which

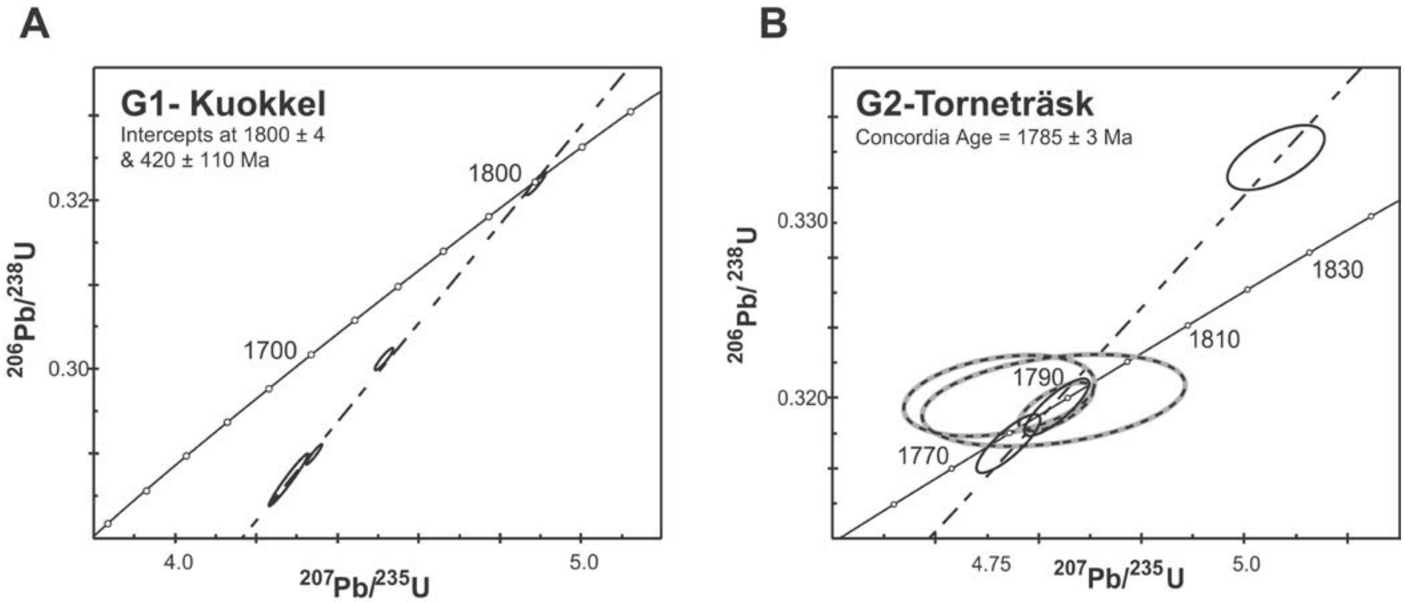

Fig. 2. U–Pb data from the granitic basement at Torneträsk. **A.** the concordant G1-zircon data point give a Concordia age of 1800±4 Ma and a discordia line anchored at this upper intercept has a lower intercept of 420±110 Ma, (MSWD=9.1). **B.** G2 data from zircon and titanite (dashed, grey error ellipses). The G2 1785±3 Ma Concordia age has a MSWD (of concordance) =0.047 and a probability (of concordance) of 0.83, calculated for two analysis. The intercept calculated from all G2 data points is 1786±4 (MSWD=1.2).

is interpreted as a disturbance of the U–Pb isotopic system during the Caledonian orogeny.

In the G2 sample we analysed both zircon and titanite due to the different closure temperature of the U–Pb isotopic systems within the two different minerals. The G2 zircon population consists of a population of dark violet, long to short prismatic grains (Table 1). Two of the analysed G2-zircon fractions, including one single grain analysis, were concordant and overlapping and the third zircon fraction is 4% inversely discordant (Fig. 2B). The upper intercept of a discordia line through the three data points coincides within error with the concordia age (Ludwig 1999) of 1785±3 Ma calculated for the two concordant zircon fractions and the likewise concordant titanite fractions. The G2 titanite population were divided into a darker and a lighter group. The lighter group had low uranium content, which affects the precision of the data, but the ages of both the light and the darker titanite fractions are identical within error.

Palaeomagnetism of Cambrian Siltstones

Thirty tested samples of the Red and Green Siltstone member have NRM intensities between 2 and 20 mAm^{-1}, bulk susceptibilities between 1.1–1.6 (10^{-3} SI units) and Curie-temperatures at around 580°C (magnetite) and 680°C (hematite);

Table 1. U–Pb data from basement zircon samples.

Fraction[a]	Weight (μg)	U (ppm)	Th/U[b]	Pbc[c] (pg)	$^{206}Pb/^{204}Pb$[d]	$^{207}Pb/^{235}U$[e]	2σ (%)	$^{206}Pb/^{238}U$[e]	2σ (%)	ρ	$^{207}Pb/^{206}Pb$[f] (Ma)	Disc.[g] (%)
G1 lfr	18	127	0.6	12.8	3596	4.889	0.39	0.3219	0.34	0.94	1802±2.5	0.2
G1 plp	6	215	0.31	10.3	2373	4.515	0.40	0.3012	0.35	0.94	1778±2.6	5.2
G1 lprfrv	163	16	0.38	20.7	4456	4.342	0.38	0.2900	0.34	0.95	1776±2.1	8.6
G1 lprp	8	228	0.34	13.5	2433	4.279	0.89	0.2869	0.87	0.98	1769±2.9	9.2
G2 ssrp	1	78	0.87	5.7	303	5.031	0.77	0.3337	0.45	0.61	1788±11	-4.4
G2 mfehv	1	177	0.70	6.1	595	4.817	0.54	0.3195	0.42	0.82	1789±5.6	0.1
G2 mfehvS	1	50	0.88	0.9	1187	4.771	0.55	0.3174	0.42	0.82	1783±5.8	0.4

Zircon analyses were corrected for blanks of 2 pg U and 0.1 pg Pb. [a] lfr = large fragments; plp = pink, long-prismatic; lprfrv = long-prismatic fragments, violet; lprp = large, prismatic pink; ssrp = small, subrounded, pink; mfehv = multifaceted, euhedral, violet; S = single grain. [b] model value calculated using the $^{208}Pb/^{206}Pb$ ratio and the age of sample, [c] total common Pb, including initial common Pb of sample and analytical blank, [d] corrected for spike contribution and fractionation, [e] corrected for spike, fractionation, blank and initial common lead, [f] corrected for spike, fractionation, blank and initial common lead, 2σ absolute errors in Ma, [g] degree of discordance.

magnetite is most pronounced. The samples respond reasonably well to both thermal (Fig. 3A) and AF (Fig. 3B) demagnetisation, but demagnetisation behaviour often becomes erratic above 600°C, or in AF fields above 60–90 mT. The bulk NRM is clearly dominated by magnetite, but thermal stability up to 670°C points to hematite as a subordinate remanence carrier. Most samples are characterised by steeply downward-dipping and northerly declinations. Low-unblocking (LB) components are typically demagnetised above 200–300°C or in AF fields of 5–10mT. LB cluster around the present day field direction, but in many cases they only marginally differs from the high unblocking (HB) components. If HB directions are of primary Cambrian origin, they are of reverse polarity (Baltica was geographically inverted in Cambrian and Early Ordovician times), but a small number of samples show HB normal polarity components carried by hematite (Fig. 3C). However, in no cases were we able to estimate stable end-directions, but great-circle analysis for seven samples yield an intersection direction with northwest declination and steep negative inclination which is antipodal to the reverse HB components (Table 3, Fig. 5).

Twenty-five samples of the Lower Siltstone member have very low NRM intensity (mean 0.3mAm^{-1}), but most samples behave stably, although with some irregularity, during AF demagnetisation (Fig. 4A). The magnetisation is primarily carried by magnetite and HB components show northeast declinations and steep positive inclinations that statistically overlap with reverse HB components from the Red and Green Siltstone member (Fig. 5).

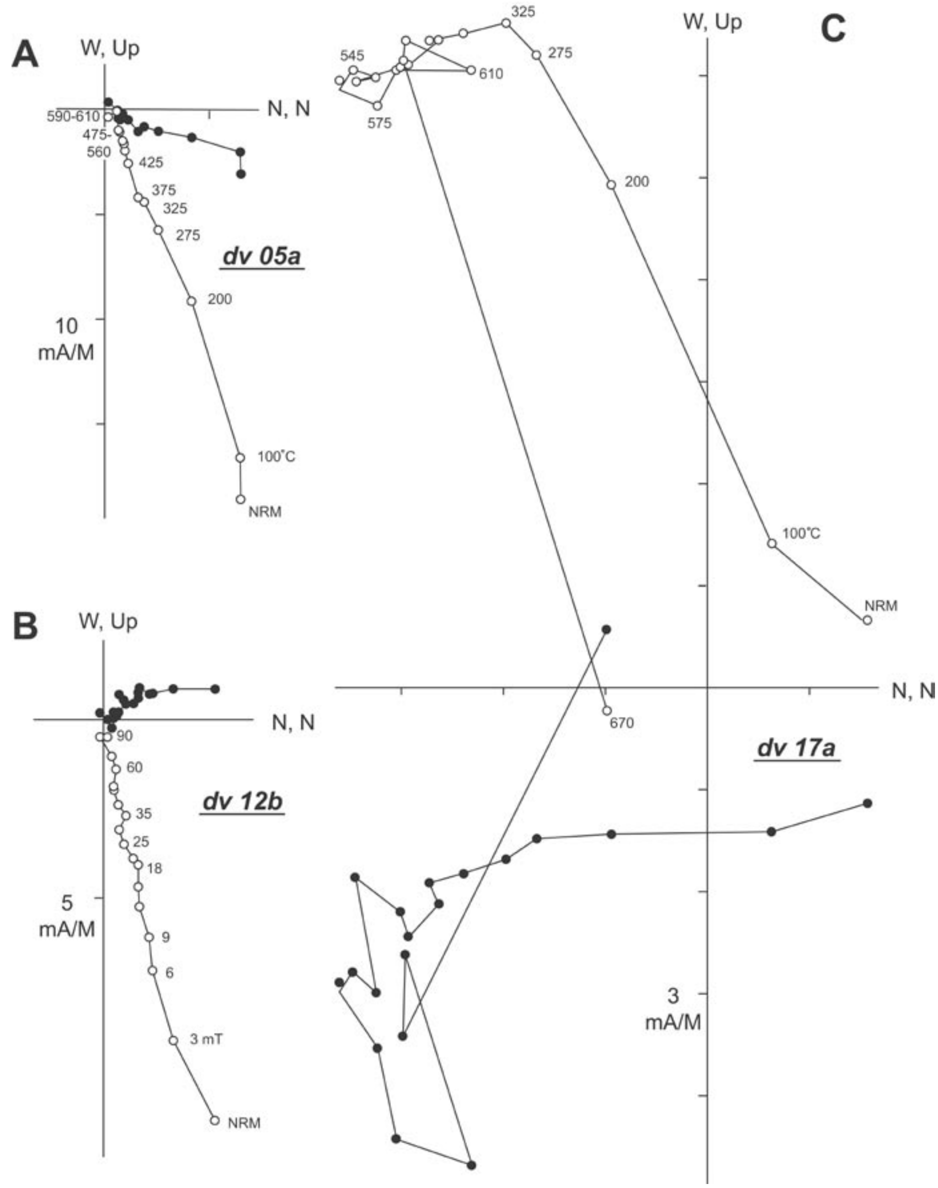

Fig. 3. Demagnetisation behaviour of the Red & Green Siltstone member (Dividalen locality), **A.** sample DV05a. **B.** sample DV12b. **C.** sample DV17a. In Zijderveld plots, open (solid) symbols denote points in the vertical (horizontal) plane.

Table 2. U–Pb data from basement titanite data.

Fraction[a]	Weight (µg)	U (ppm)	Th/U[b]	Pbc[c] (ppm)	^{206}Pb/^{204}Pb[d]	^{207}Pb/^{235}U[e]	2σ (%)	^{206}Pb/^{238}U[e]	2σ (%)	ρ	^{206}Pb/^{238}U[f] (Ma)	Disc.[g] (%)
G2 d	28	45	0.28	2.30	332	4.816	0.62	0.3194	0.36	0.64	1787±6	0.1
G2 l1	11	29	1.90	4.77	123	4.817	2.20	0.3199	0.65	0.37	1789±10	-0.2
G2 l2	11	29	1.90	4.79	123	4.762	1.60	0.3201	0.59	0.34	1790±9	-1.7

Titanite analyses were corrected for blanks of 2 pg Pb and 0.1 pg U. [a] d = dark; l = light, [b] model value calculated using the ^{208}Pb/^{206}Pb ratio and the age of sample, [c] total common lead in sample, including initial common Pb of sample and analytical blank, [d] corrected for spike contribution and fractionation, [e] corrected for spike, fractionation, blank and initial common lead, [f] corrected for spike, fractionation, blank and initial common lead, 2σ absolute errors in Ma, [g] degree of discordance.

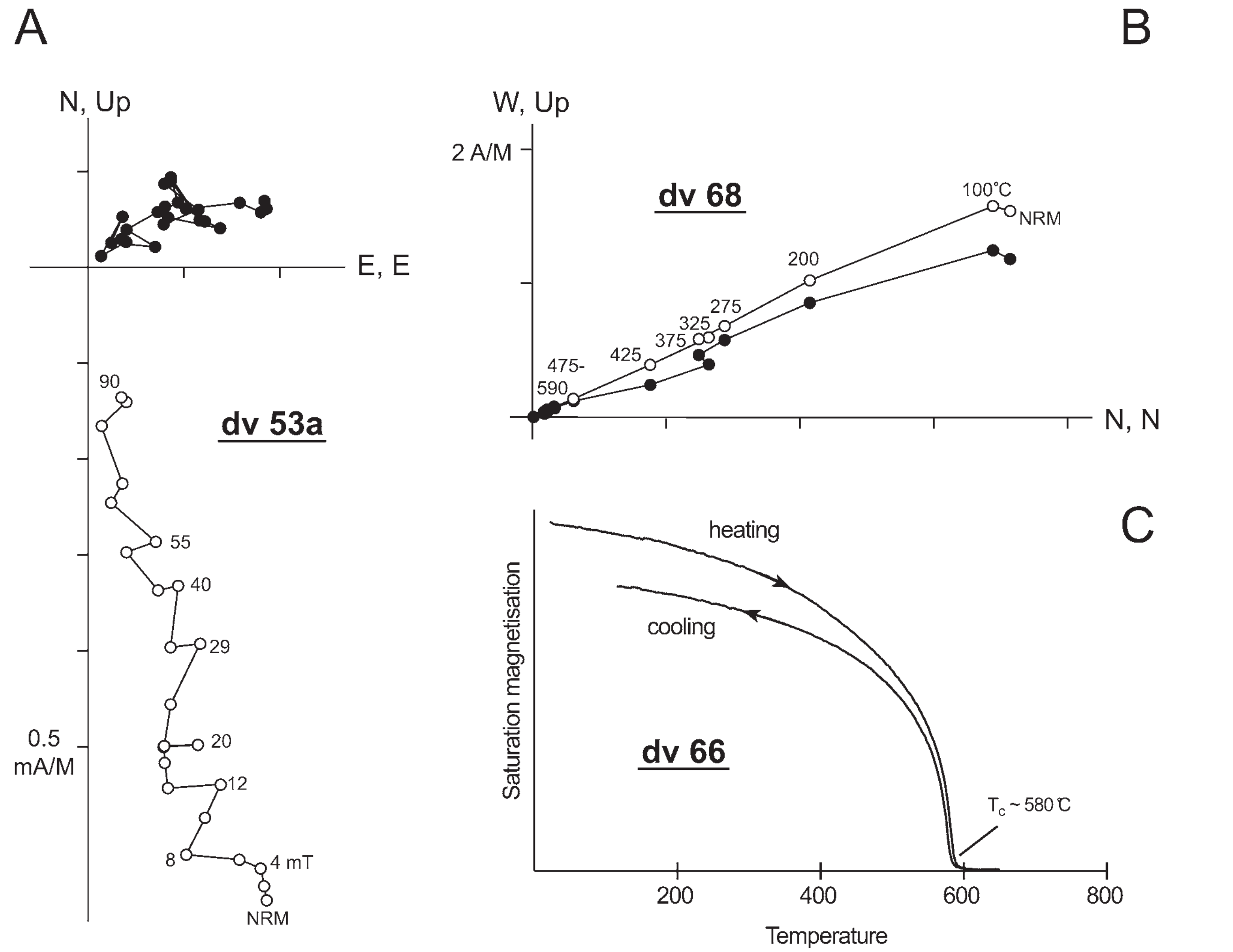

Fig. 4. Demagnetisation behaviour of the Lower Siltstone member. **A.** sample DV53a (Vakkejokk locality), and the basement granite (G2 locality). **B.** sample DV68. **C.** Curie temperature for a basement granite sample (G2 locality).

Table 3. Site mean directions (high unblocking) from the Dividal Group and underlying granite basement (mean sampling coordinates: 68.2°N, 19.5°E).

Site[a]	member[b]	N[c]	α95[d]	Dec[e] In situ	Inc[e] In situ	Dec[e] Bedding corrected	Inc[e] Bedding corrected	Strike	Dip
B93	Red	8	10	63	67	56	68	210	3
T1	LSilt	4	16.5	109	77	109	77	-	-
T2	LSilt	7	13.5	49	70	49	70	-	-
T3	LSilt	7	17.8	238	–58	238	–58	-	-
T4	Red	9	3.8	47	60	47	60	-	-
T5	Red	11	7.0	50	58	50	58	-	-
DIV	Red	19	10.3	8	83	27	66	305	17
DIV-GC	Red	7	10#	207	–73	211	–56	305	17
VAK	LSilt	18	16.4	63	70	63	70	-	-
Mean Sites		9*	7.2	54	70	50	66	(α95=6.9)	
			Pole: 58.4°N, 122.5°E (dp/dm=9.2/11.3)						
G2	granite	7	11.8	333	–19	-	-	-	-
			Pole: 9.8°N, 226.7°E (dp/dm=6.4/12.3)						

[a] B93= Bylund 1994, T1–T5 = Torsvik & Rehnström 2001, DIV = Dividalen (this study), VAK = Vakkejokk (this study), GC = great circle intersection; [b] Red = Red and Green Siltstone member; LSilt = Lower Siltstone member; [c] N = samples, * = sites; [d] α_{95}= 95% confidence circle (# = MAD); [e] Dec/Inc = mean declination/ inclination; dp/dm = 95% semi-axis ovals around the pole. Normal polarity sites (T3, DIV-GC) have been inverted for mean calculations.

Regional field stability test

A regional field test involved pilot analyses of the remanent magnetisation of the basement immediately underlying the Dividal Group. The sampled granite (G2), see Fig. 1, displays remarkably stable behaviour during both thermal (Fig. 4B) and AF demagnetisation. Curie temperatures and maximum unblocking temperatures at around 580–590°C suggest magnetite (Fig. 4C) as the prime remanence carrier. All samples are almost single component with northwest declinations and shallow negative inclinations (Figs. 4B), and are thus very different from the overlying Dividal Group (Fig. 5).

Discussion

The U–Pb data from the G1 granite (Kuokkel Window) yielded one concordant data point with a concordia age of 1800±4 Ma, which is interpreted as the age of crystallisation (Fig. 2A). The lower intercept at 420 Ma has a large error, but is interpreted as a disturbance of the U–Pb isotopic system during the main Silurian phase of the Caledonian orogeny. This is also in accordance with the observation that these rocks are more deformed than G2, have themselves been interpreted to be allochthonous (Romer & Bax 1992). The age is compatible with Rb–Sr and U–Pb ages of about 1.79 Ga from the Kuokkel Window itself (Romer & Wright 1994) and from the Rombak and Sjangeli Windows (Gunner 1981; Romer et al. 1991), to the west and southwest of Lake Torneträsk. No trace of any Neoproterozoic disturbance was detected although crystallisation ages are in the same range as allochthonous granites further south (Rehnström et al. 2002; Rehnström 2003). All the data points from the G2 granite (Lake Torneträsk) are concordant expect one zircon analysis that is slightly inversely discordant. The concordia age of 1785±3 Ma (Fig. 2B) is interpreted as the age of crystallisation.

The granitoid basement in the eastern part of Lake Torneträsk, where G2 was sampled, is largely unaffected by Caledonian influence and belongs to the Lina Granite Suite (Silvennoinen et al. 1987). Martinsson et al. (1999) sampled the Lina Granite north of Lake Torneträsk and dated it to 1696±55 Ma. These analyses are very strongly discordant and the resulting age rather uncertain due to secondary lead loss. The hitherto best estimate of the age of the Lina Granite comes from Kalix in northeastern Sweden, where combined U–Pb analyses on zircon and monazite yields an age of 1783±3 Ma (Wikström & Persson 1997).

The palaeomagnetic data from the 1785 Ma G2 granite are of excellent quality and clearly distinguishable from the data from the overlying Dividal Group (Fig. 5). The unaffected U–Pb system in both zircon and titanite may also increase the probability that a primary remanent magnetisation survived in the granite as well as in the overlying Cambrian sediments. However, the 1785 Ma granite pole does not match similar aged poles from Baltica,

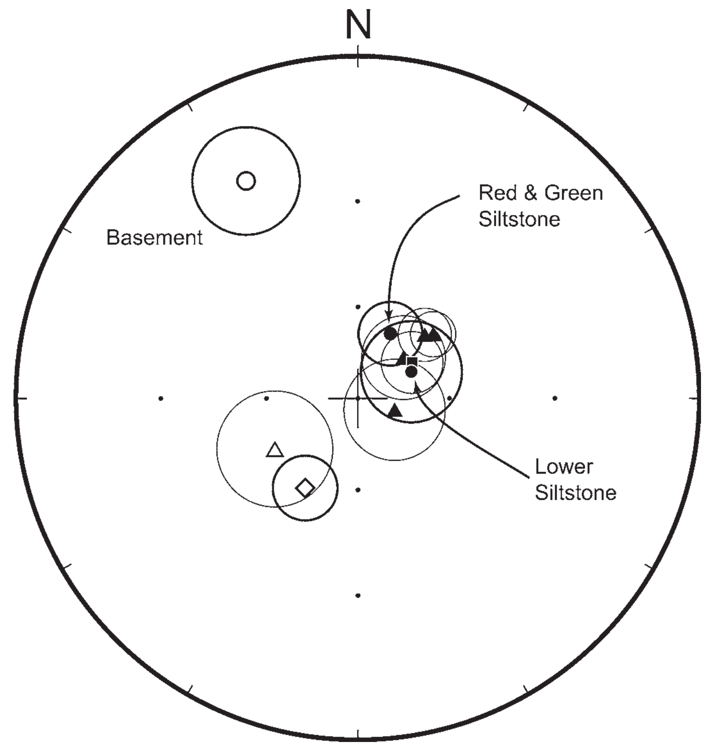

Fig. 5. Bedding corrected site means from the Cambrian Dividal Group; ● – Dividal Group, this study; ◇ – great circle; ■ – Dividal Group from Bylund (1994); △ – Dividal Group from Torsvik & Rehnström (2001); O – basement granite. In stereoplot, open (filled) symbols represent negative (positive) inclinations.

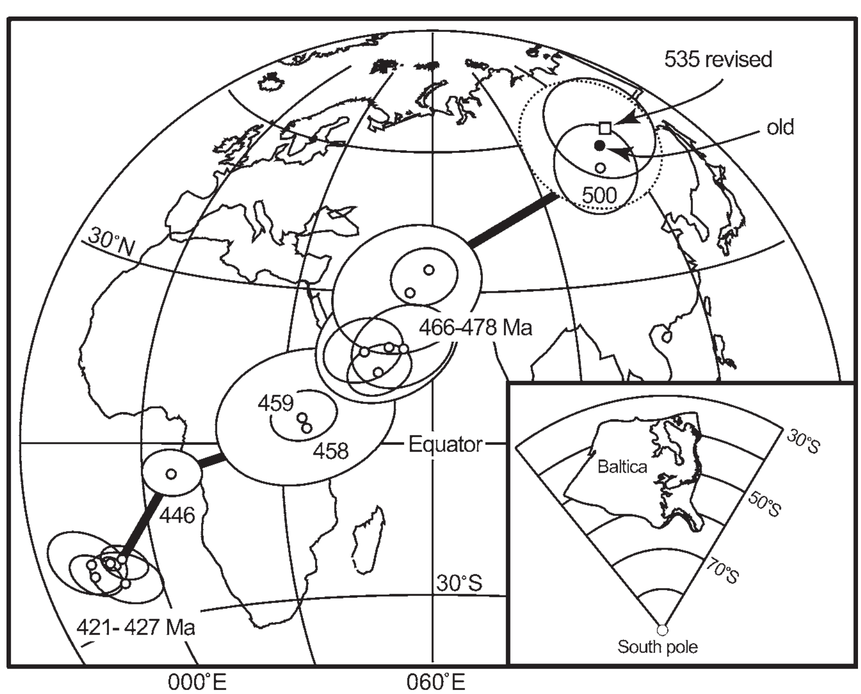

Fig. 6. Cambrian to Silurian palaeomagnetic poles from Baltica (after Torsvik & Rehnström 2001) and the refined ~535 Ma Dividal Group palaeopole (Table 3). All poles are shown with dp/dm semi-axis. Inset shows a reconstruction of Baltica at 535 Ma using the mean pole listed in Table 3.

which suggest (1) a local or regional tectonic explanation, (2) a Precambrian remagnetisation event or (3) secular variation (our single sampling site should and must be regarded as a spot-reading of the geomagnetic field).

The Early Cambrian palaeomagnetic data from the new sites at Dividalen and Torneträsk match previously reported Dividal Group results (Fig. 5; Table 3), and we have therefore combined all Dividal Group sites to calculate a refined Early Cambrian pole for Baltica. Most Dividal sites are flat-lying; hence, a fold-test is statistically inconclusive. Moreover, most sites are of reverse polarity (Fig. 5), but an antipodal reversal in the Lower Siltstone member (Torsvik & Rehnström 2001), and indication of a second reversal in the Red and Green Siltstone member (estimated with the great-circle method; this study) suggest a primary, or near-primary magnetisation. No signs of a Silurian remagnetisation, possibly linked to Caledonian thrusting above the sampling sites (Fig. 1), are detected. A Silurian remagnetisa-tion would be expected to have produced palaeomagnetic directions with northeast declinations and negative inclinations (or antipodal southwest declinations and positive inclinations), and very different pole positions (compare location of 421–427 Ma poles and refined 535 Ma pole in Fig. 6). Based on these considerations and the fact that the immediate underlying basement granite does not show any signs of *Phanerozoic* remagnetisation, we argue that the magnetisation, and hence the palaeomagnetic pole from the Early Cambrian sediments are likely to be of primary origin. The alternative interpretation would involve a Late Mesozoic–Tertiary dual polarity overprint that did not affect the basement.

The two new palaeomagnetic sites reported here refine the palaeomagnetic pole determined by Bylund (1994) and Torsvik & Rehnström (2001) for the Early Cambrian of Baltica (Table 3; Fig. 6). The 535 Ma Dividal Group either predates or overlaps with the postulated age interval of 90° TPW (535–520 Ma). This, along with a preliminary Late Cambrian pole (500 Ma pole in Fig. 6) that statistically overlaps with the Dividal Group Pole, does not support rapid TPW during the Cambrian. Admittedly, the Cambrian poles from Baltica are not of the same quality as the Ordovician poles in Fig. 6, but we have exhausted good sampling targets within Scandinavia, and future Cambrian results must probably be derived from other regions within Baltica.

Conclusions

The remanent magnetisation of the Early Cambrian Dividal Group is interpreted as primary, and there are no traces of any Scandian (Silurian) magnetic overprint that could be linked to Caledonian thrusting in the area. Our new palaeomagnetic data overlap with previous results, and a combined palaeomagnetic pole places Baltica at intermediate to high southerly latitudes (35–65°S) and geographically inverted in the Early Cambrian. The granite basement immediately underlying the Caledonian allochthon in the eastern Torneträsk area is 1785±3 Ma old and carries a remanent magnetisation that is clearly pre-Phanerozoic. The basement in the allochthonous Kuokkel Window is 1800±4 Ma and show evidence of a Mid-Palaeozoic disturbance in the U–Pb isotopic system, interpreted as partial lead-loss during the Caledonian orogeny.

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